[0001] The present invention relates to apparatus and methods for defining optical signal paths in a photosensitive material. In one aspect, the present invention relates to an optical waveguide router that may be dynamically adapted by the use of a scanning system.

BACKGROUND TO THE INVENTION

[0002] Routers are known in the art. A router is a device which routes and interconnects one, or many, network inputs to one or many network outputs through a variety of techniques. Optical routers are used to route incoming optical signals from one or more network inputs to one or more optical outputs. Optical fibres are typically used to apply and collect optical signals at the input and output ports. Methods known in the art for performing this routing on incoming optical signals include the use of patch panels, mechanical, thermo-optic, electro-optic and opto-electronic switching.

[0003] Patch panels have obvious drawbacks including requiring manual effort (i.e. human intervention) to alter the configuration of the patch panel. This manual manipulation to reconfigure the optical routing of signals in a patch panel can be quite time consuming and therefore costly. Moreover, patch panels do not allow for remote configuration of the routing signals.

[0004] Mechanical switches use electrical actuators, such as motors or solenoids, to physically move fibres or optical elements to alter to routing of the signal. While remote configuration of such a system is possible, it relies on mechanical translation, which is inherently slow and has limited configuration possibilities.

[0005] Devices using thermo-optic switches are remotely reconfigured through the use of materials which have indices of refraction which are temperature dependent. By changing the temperature (e.g. through the use of a dissipative element such as a resistor) the index of refraction of a waveguide can be altered, thereby allowing the construction of a switch to alter the path of an incoming optical signal. However, thermo-optic crosspoints built from such switches have a limited and fixed number of routing paths available since the waveguides are fixed resulting in a limited ability to reconfigure the crosspoint device. Moreover, the response time, that is the time taken to alter the refractive index at the thermo-optic crosspoint, is not sufficiently fast to allow for the deployment of the crosspoint device into a number of applications. Finally, to maintain the desired routing, the thermo-optic crosspoint requires that a waveguide or juncture be maintained at the required temperature otherwise the applied thermal energy will dissipate returning the thermo-optic switch's index of refraction to its original, or initial, value. As such, the thermo-optic crosspoint, in response to power outage will lose all routing connections that existed prior to the outage.

[0006] Electro-optic devices operate in a similar manner to the thermo-optic devices, described above, except the change in refractive index is accomplished by the application of an electric field. These devices may be switched quickly with sufficiently large applied fields but are intrinsically sensitive to the polarisation of the incoming light. This polarisation sensitivity makes them unusable or very cumbersome to use in the majority of cases. In addition, these devices require patterned metal electrodes to apply the electric field which complicates the device's manufacture.

[0007] An optical router can also be implemented through opto-electronic means by using optical-to-electrical converters followed by an electrical switch/router and then electrical-to-optical converters. Although this method does have advantages in some applications (such as the ability to do signal

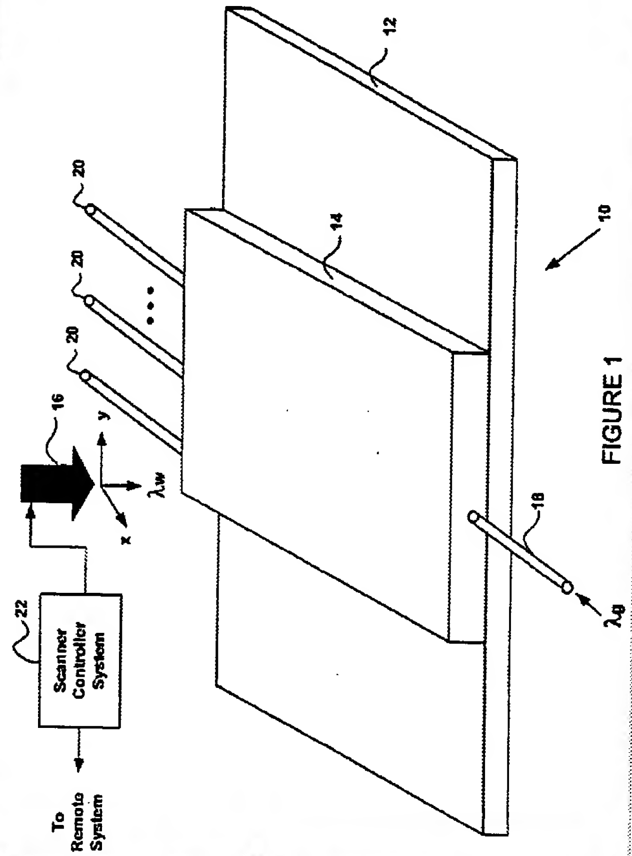

FIGURE 1

FIG. 15(b) is a perspective view which shows a magneto-optical modulator o the eleventh embodiment;

FIG. 16 is a block diagram which shows a magneto-optical modulator accordi to the twelfth embodiment of the invention;

FIG. 17(a) is a front view which shows a structure of a high-frequency fie generator installed in a magneto-optical modulator according to the thirteent embodiment of the invention;

FIG. 17(b) is a perspective view which shows a magneto-optical modulator according to the thirteenth embodiment of the invention;

FIG. 18 is a block diagram which shows a magneto-optical modulator accordi to the fourteenth embodiment of the invention;

FIG. 19(a) is a plan view which shows an optical modulating device accordi to the fifteenth embodiment of the invention; and

FIG. 19(b) is a perspective view which shows a magneto-optical modulator o the fifteenth embodiment.

DETAILED DESCRIPTION:

(1) DESCRIPTION OF THE PREFERRED EMBODIMENTS

(2) Referring to the drawings, wherein parts designated by like terms have like structures in several views unless otherwise specified, particularly to FIG. 1, there is shown an optical signal transmission system equipped with a magneto-optical modulator 150 according to the first embodiment of the invention.

(3) An optical carrier wave or light emitted from a light source 101 travel through an optical fiber 8 and enters the magneto-optical modulator 150 which utilizes the Faraday effect of a magneto-optical element 1. The magneto-optical modulator 150 consists of a polarizer 2, the magneto-optical element 1, an analyzer 3, a high-frequency field generator 5, an impedance adjuster 6, and a dc field generator 4. The magneto-optical element 1 is mad of, for example, a bulk crystal, a polycrystal sintered body, a crystal film formed by, for example, the vapor phase epitaxy, or a composite containing resin and ferromagneto-optical material dispersed in the resin. The high-frequency field generator 5 works to apply a high-frequency field to the magneto-optical element 1. The impedance adjustor 6 works to adjust the electrical impedance of the high-frequency field generator 5. The magneto-optical modulator 150 is responsive to an electric signal (i.e., a high-frequency modulating signal) inputted from a high-frequency generator 7 modulate the light transmitted through the optical fiber 8 as a function of t high-frequency modulating signal. The modulated light is outputted through a optical fiber 9 and converted in an optical receiver 102 into an electric signal, which is, in turn, demodulated through an amplifier and a signal processing circuit (not shown).

(4) The impedance adjustor 6 works to adjust the impedance of the high-frequency field generator 5 so as to establish effective transmission of the signal from the high-frequency generator 7 to the high-frequency field generator 5. FIG. 10 shows comparison between the presence and absence of th impedance adjuster 6. In the illustrated cases, the high-frequency field generator 5 is made up of 16 to several tens of turns of wire around the magneto-optical element 1. In the absence of the impedance adjuster 6, the

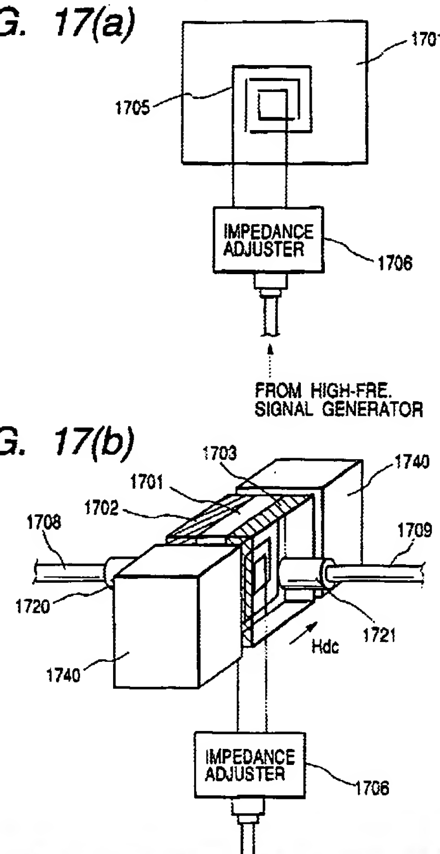

FIG. 17(a)
FIG. 17(b)

FIG. 15(b) is a perspective view which shows a magneto-optical modulator o the eleventh embodiment;

FIG. 16 is a block diagram which shows a magneto-optical modulator accordi to the twelfth embodiment of the invention;

FIG. 17(a) is a front view which shows a structure of a high-frequency fie generator installed in a magneto-optical modulator according to the thirteent embodiment of the invention;

FIG. 17(b) is a perspective view which shows a magneto-optical modulator according to the thirteenth embodiment of the invention;

FIG. 18 is a block diagram which shows a magneto-optical modulator accordi to the fourteenth embodiment of the invention;

FIG. 19(a) is a plan view which shows an optical modulating device accordi to the fifteenth embodiment of the invention; and

FIG. 19(b) is a perspective view which shows a magneto-optical modulator o the fifteenth embodiment.

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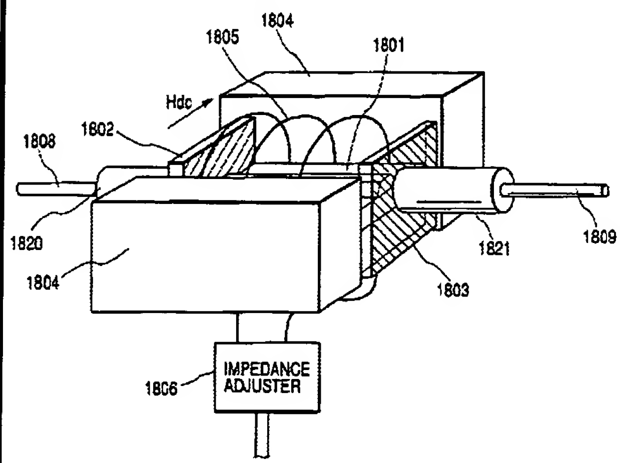
FIG. 18



with a filler material. The filler material may comprise, for example, a commercially available pliable adhesive (e.g., silicone). Attaching optical fibers 36 and 38 to the inner surface of bend limiter tubing 40 facilitates t automated assembly process by reducing the motion of optical fibers 36 and 38 The filler material reduces axial motion of optical fibers 36 and 38 in the directions indicated by arrow 48. Axial motion may be caused by mechanical strain applied to optical fibers 36 and 38 during the assembly process. Axia motion may also be caused by expansion and contraction of optical fibers 36 a 38, and/or other components, due to thermal variation. Excessive axial motio may cause optical fibers 36 and 38 to bend and ultimately sustain damage. Th filler material also reduces radial motion of optical fibers 36 and 38, thus reducing the possibility of any damage due to radial motion.

(11) Support member 42 provides support for bend limiter tubing 40 and optical fibers 36 and 38. In an exemplary embodiment of the invention, optic fibers 36 and 38 are rigidly attached to collimated lens assembly 50. This rigid attachment also contributes to the bending of optical fibers 36 and 38 when subjected to axial motion. The support provided by support member 42 reduces bending of optical fibers 36 and 38, and reduces the possibility of optical fibers 36 and 38 becoming detached from collimated lens assembly 50. In an exemplary embodiment of the invention, bend limiter tubing 40 is attach to support member 42. Attachment of bend limiter tubing 40 to support member 42 may be achieved through the use of, for example, an adhesive such as epoxy Attachment of bend limiter tubing 40 to support member 42 facilitates the automated assembly process by reducing movement of bend limiter tubing 40, which in turn reduces movement of optical fibers 36 and 38.

(12) It is emphasized that the embodiment of the invention shown in FIG. 3 exemplary. FIG. 3 shows two optical fibers, 36 and 38. FIG. 3 shows support member 42 as an integral part of base structure 20. It is envisioned that ba structure 20 and support member 42 may be separate, but rigidly attached by a appropriate means such as adhesively, snap fit, press fit, or bolted.

(13) FIG. 4 is an exploded view of an optical component assembly, in a plan configuration, in accordance with the present invention. Region 24 within th housing, may retain any combination of optical components. Optical component 54 and 56 represent exemplary optical components which may be retained in region 24, examples of which include lenses, reflectors, isolators, taps, and WDMs. In the exemplary embodiment of the invention shown in FIG. 4, optical component 54 is an isolator and optical component 56 is a prism. In this embodiment, isolator 54 ensures that optical energy is directed toward optica component 56 with minimal reflection of optical energy back toward collimated lens assembly 50. Optical energy which has interacted with isolator 54 is directed toward prism 56. Prism 56, apportions and routes the optical energy received from isolator 54 to collimated lens assemblies 51 and 53.

(14) Isolator 54 and prism 56 form a free air space optical network. Optic energy is coupled between window 26 and isolator 54, between isolator 54 and prism 56, and between prism 56 and window 28, through air. A free air space optical network may not be appropriate in an environment with high ambient optical energy. In high ambient optical energy environments, it is advantageous to provide a cover, such as upper portion 52 over region 24. Upper portion 52 also protects optical components within region 24 from damag (e.g., dust, collision, contamination) during storage, shipping, and use. Opening 70, in upper portion 52 may remain open or be filled with material. example of a filler material for hole 70 is a membrane comprising a wicking agent to withdraw moisture from region 24.

(15) Upper portion 52 is positioned opposite base structure 20 and support members 42. Upper portion 52 is attached to base structure 20 and/or support

U.S. Patent Feb. 4, 2003 Sheet 4 of 5 US 6,513,992 B2

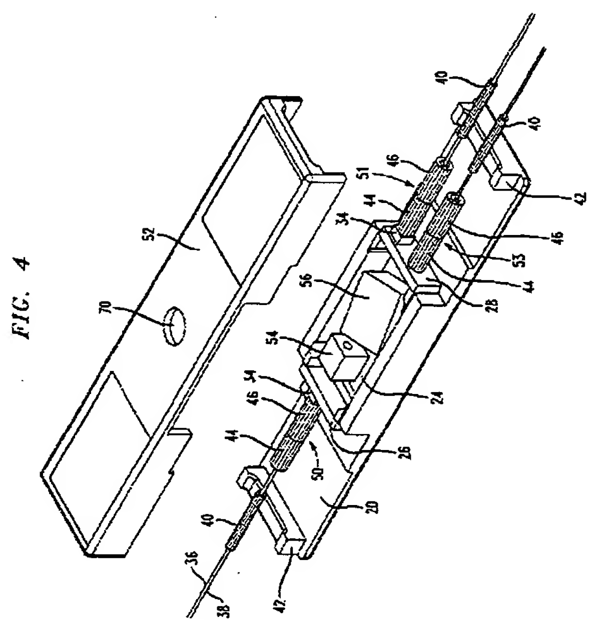


FIG. 4

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US-PAT-NO: 6438295

DOCUMENT-IDENTIFIER: US 6438295 B1

TITLE: Adaptive optical waveguide router

DATE-ISSUED: August 20, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE
McGarry; Steven P.	Carp	N/A	N/A
MacPherson; Charles D.	Ottawa	N/A	N/A

ASSIGNEE INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTR
Nortel Networks Limited	St. Laurent	N/A	N/A	CA

APPL-NO: 09/ 412437

DATE FILED: October 5, 1999

INT-CL: [07] G02B006/26

US-CL-ISSUED: 385/39, 385/2 , 385/8 , 385/16 , 385/31 , 385/132

US-CL-CURRENT: 385/39 , 385/132 , 385/16 , 385/2 , 385/31 , 385/8

FIELD-OF-SEARCH: 385/39; 385/2 ; 385/8 ; 385/15 ; 385/16 ; 385/31 ; 385/130-132 ; 385/140

REF-CITED:

U.S. PATENT DOCUMENTS

PAT-NO	ISSUE-DATE	PATENTEE-NAME
5136669	August 1992	Gerdt
N/A	N/A	

ART-UNIT: 2872

PRIMARY-EXAMINER: Spyrou; Cassandra

ASSISTANT-EXAMINER: Assaf; Fayez

ABSTRACT:

An adaptive optical waveguide router in which routing paths may be dynamically created by the use of a scanning system. The optical router interconnects at least one optical input to a at least optical output. The optical waveguide layer employed is substantially comprised of a photosensiti material which has a change in index of refraction at one optical wavelength when exposed to a different optical wavelength and which, in some way, may be restored to it's original state. One such material is Bacteriorhodopsin whic shows a photocycle in the visible region of the optical spectrum. The scanni system, in response to routing information, traces a routing path(s) between input(s) and a selected output(s) which alters the index of refraction in the path(s) traced in the photorefractive material. An optical input signal then propagates along the traced path between the selected input(s) and the select

2/5

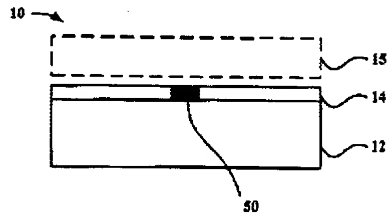
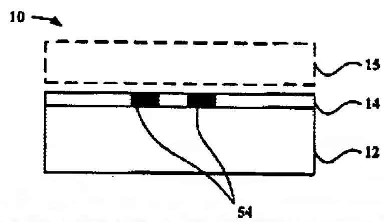


Figure 2A



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PAT-NO: JP360158409A

DOCUMENT-IDENTIFIER: JP 60158409 A

TITLE: LIGHT OUTPUT MONITOR OF LIGHT EMITTING DIODE

PUBN-DATE: August 19, 1985

INVENTOR-INFORMATION:
NAME
OMAE, YOSHINOBU

ASSIGNEE-INFORMATION:

NAME	COUNTRY
SHIMADZU CORP	N/A

APPL-NO: JP59014043

APPL-DATE: January 27, 1984

INT-CL (IPC): G02B006/28

US-CL-CURRENT: 356/221

ABSTRACT:

PURPOSE: To obtain always an exact monitor value by passing the output light from a light emitting diode through a mode scrambler formed by curving an optical fiber having a prescribed diameter at prescribed curvature then branching the light and conducting the same to a photodetector.

CONSTITUTION: The output light from an LED1 is introduced into a mode scrambler 5 formed by curving an optical fiber . The light past the scrambler 5 is branched by optical fibers 2a, 2b and the light propagating in the fiber 2a is supplied as a light source for an apparatus via a fiber connector adapter 3. The light past the inside of the fiber 2b is conducted to and monitored by a photodetector 4. The output light from the LED1 is passed by the scrambler 5 by which the output light distribution from the exit end of the scrambler 5 is made always uniform irrespectively of the change in the exit pattern of the LED1. The curved part having about ≤5mm radius of curvature is provided by using the optical fiber having, for example, 125μm core diameter as the scrambler 5. The exact monitor value is thus obtd.

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US-PAT-NO: 5555330

DOCUMENT-IDENTIFIER: US 5555330 A

TITLE: Wavelength division multiplexed coupler with low crosstalk between channels and integrated coupler/isolator device

DATE-ISSUED: September 10, 1996

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE
Pan; Jing-Jong	Milpitas	CA	N/A
Shih; Ming	Milpitas	CA	N/A
Xu; Jingyu	San Jose	CA	N/A

ASSIGNEE INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
E-Tek Dynamics, Inc.	San Jose	CA	N/A	N/A

APPL-NO: 08/ 361610

DATE FILED: December 21, 1994

INT-CL: [06] G02B006/26

US-CL-ISSUED: 385/39, 385/11 , 385/14 , 372/703 , 359/494

US-CL-CURRENT: 385/39 , 359/494 , 372/703 , 385/11 , 385/14

FIELD-OF-SEARCH: 385/39; 385/11 ; 385/14 ; 385/15 ; 385/74 ; 372/703 ; 359/4 ; 359/485 ; 359/487 ; 359/488 ; 359/494 ; 359/495 ; 359/497 ; 359/499

REF-CITED:

U.S. PATENT DOCUMENTS

PAT-NO	ISSUE-DATE	PATENTEE-NAME		
5082343	January 1992	Coult et al.	N/A	N/A
5134621	July 1992	Marshall	N/A	N/A
5315431	May 1994	Masuda et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

FOREIGN-PAT-NO	PUBN-DATE	COUNTRY	US-CL
2-248919	October 1990	JP	372/703
6-24716	February 1994	JP	372/703
6-27417	February 1994	JP	372/703

ART-UNIT: 251

PRIMARY-EXAMINER: Bovernick; Rodney B.

ASSISTANT-EXAMINER: Sanghavi; Hemang

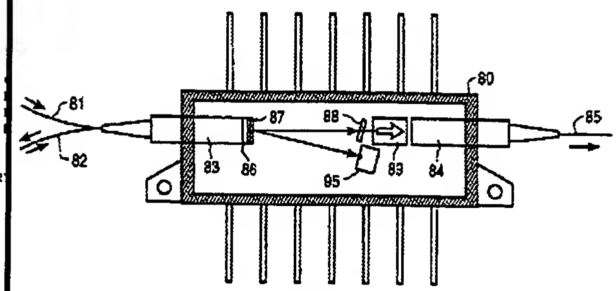


FIG. 5

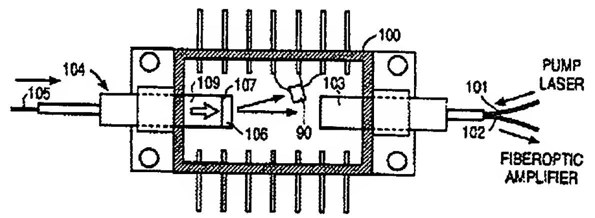
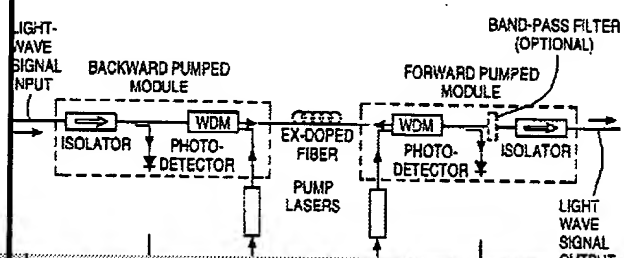


FIG. 7



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US-PAT-NO: 4168107

DOCUMENT-IDENTIFIER: US 4168107 A

TITLE: Multimode optic device

DATE-ISSUED: September 18, 1979

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE
Sauter; Gerald F.	Eagan	MN	N/A

ASSIGNEE INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTR
Sperry Rand Corporation	New York	NY	N/A	N/A

APPL-NO: 05/ 891881

DATE FILED: March 30, 1978

INT-CL: [02] G02B005/14

US-CL-ISSUED: 350/96.13, 350/96.19 , 350/151 , 350/162R

US-CL-CURRENT: 385/6, 385/39 , 398/143 , 398/87

FIELD-OF-SEARCH: 350/96.13; 350/96.14 ; 350/96.15 ; 350/96.19 ; 350/151 ; 350/162R

REF-CITED:

U.S. PATENT DOCUMENTS

PAT-NO		ISSUE-DATE	PATENTEE-NAME
3752563		August 1973	Torok et al.
N/A	N/A		
4082424		April 1978	Sauter et al.
N/A	N/A		

ART-UNIT: 257

PRIMARY-EXAMINER: Levy; Stewart J.

ATTY-AGENT-FIRM: Grace; Kenneth T. Cleaver; William E. Truex; Marshall M.

ABSTRACT:

Disclosed is a solid state apparatus for and a method of (1) modulating th intensity of a multimode light beam; (2) coupling the light beam to an input optic fiber that is butt coupled to a diffraction grating that is formed of a plurality of stripe domains in a magnetic film; (3) altering, by the application of suitable magnetic fields, the angular orientation of the strip domains in the plane of the magnetic film, and (4) multiplexing the diffracte light beam to a selected one of a plurality of several output optic fibers. The apparatus uses a liquid-phase epitaxially (LPE) grown film of bismuth substituted rare earth iron garnet to form a magnetizable layer in which stri domains may be generated, sustained and moved about. The stripe domains form diffraction grating. The angular orientation of the stripe domains in the

U.S. Patent Sep. 18, 1979 Sheet 3 of 5 4,168,107